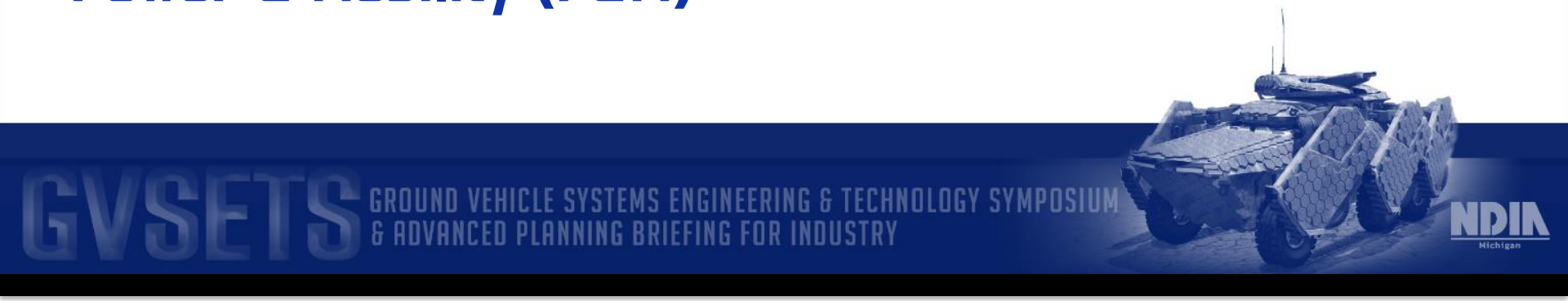
Power & Mobility (P&M)



Advanced Nonflammable Battery

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ACKNOWLEDGEMENTS

This material is based upon work supported by the Army Contracting Command - Warren, under Contract No. W56HZV-21-C-0075. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Army Contracting Command - Warren.

DISTRIBUTION A.

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Presentation Outline

Company Overview

Cell Design

Cell Performance

Applications

CRG Overview

Aerospace & Defense Company

Founded in 1997 in Dayton, Ohio

Partnered with Most DOD Prime Contractors

Substantial Technology Portfolio Ready for Commercialization

Successfully Launched Multiple Subsidiaries

SPINTECH 2010

Advantic 2014

kineticure 2014

AP AgilePower 2020

lectratek powering eAviation 2020

Battery & Cell Development Labs

Facility

- 174,000 ft^2 (total)
- >5400 ft^2 for cell and battery development, assembly, and test

Battery Cell Manufacturing

- 1000 ft^2 Dry Room
- Li-ion & Li-metal capable (dew point < -40°C)
- Semi-Automated Pilot Line
    - Pouch Cells (approximately 30 x 40 mm to 100 x 100 mm)
    - Li-metal compatible

Battery Cell Assembly Pilot Line

Presentation Outline

Company Overview

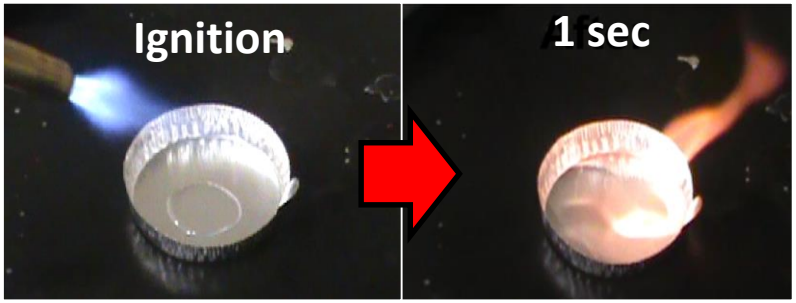
Cell Design

Cell Performance

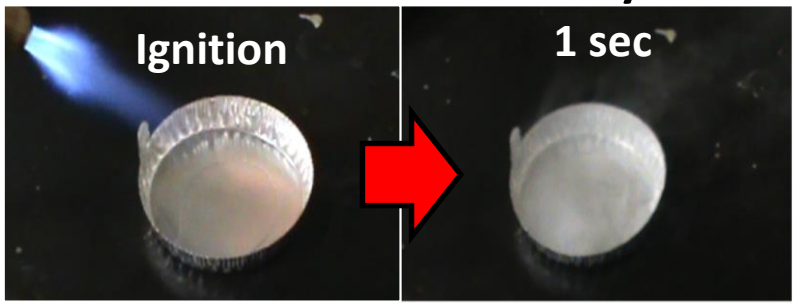
Applications

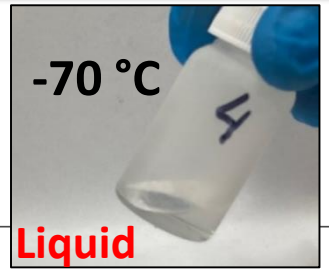
Electrolyte

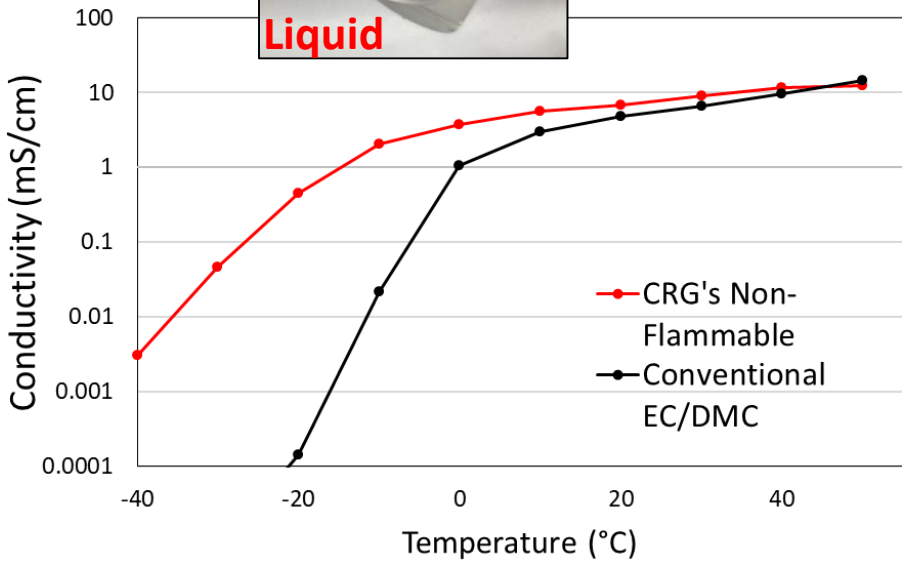
EC/DMC Electrolyte



Nonflammable Electrolyte



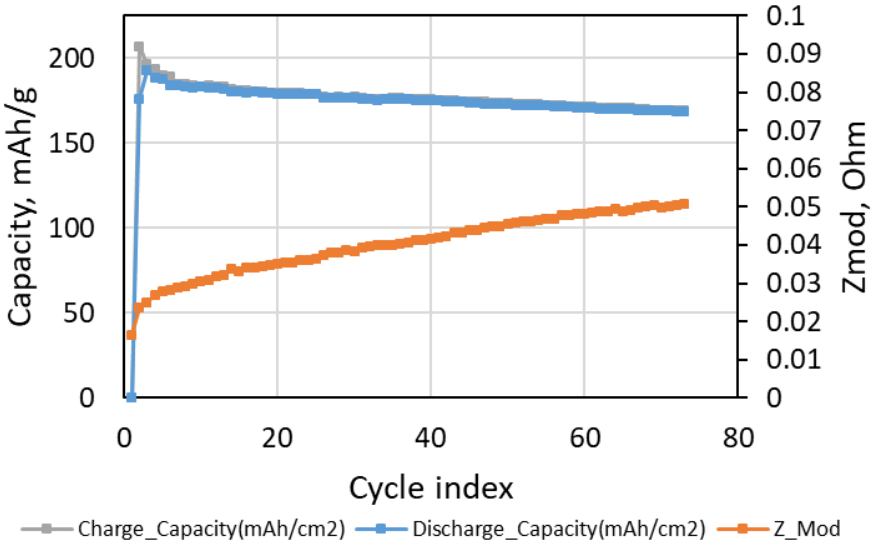




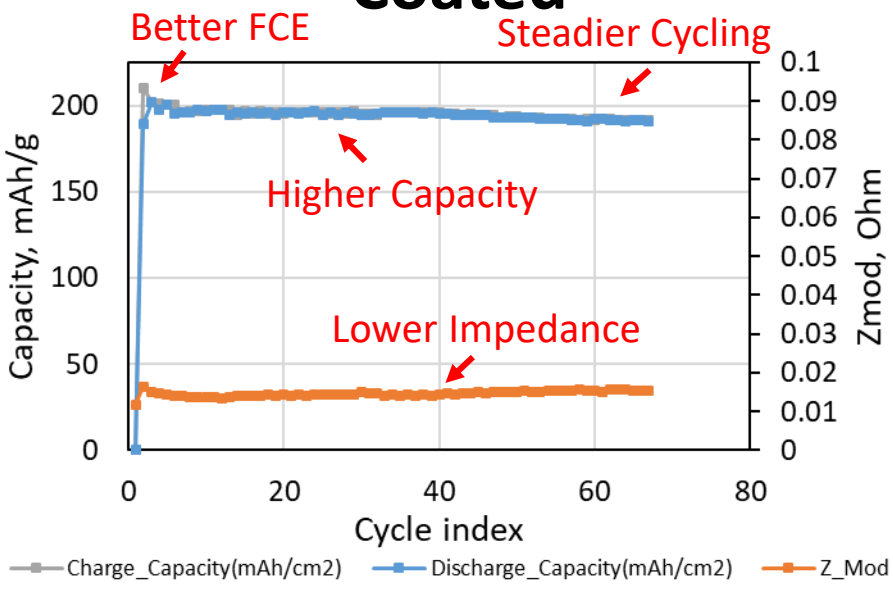
CRG developed a nonflammable low-temperature electrolyte with exceptional performance

Coating Performance

Uncoated



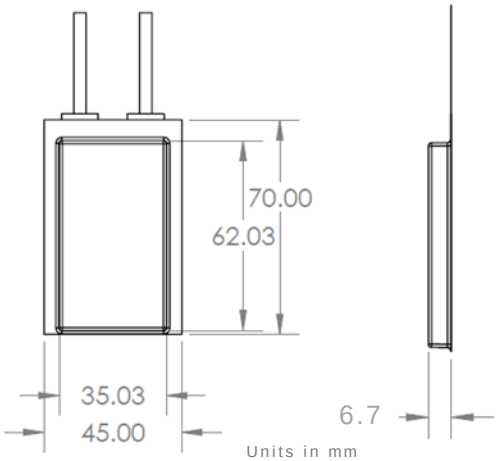
Coated

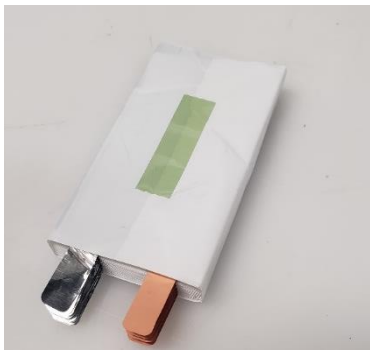


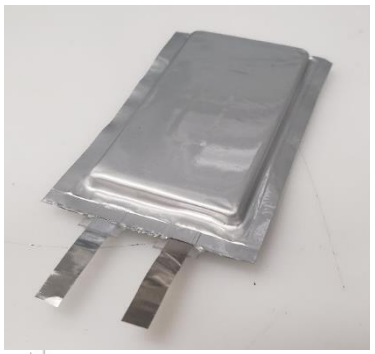
Cathode coating has several beneficial electrochemical characteristics

Non-Flammable Cell

Specifications	
Size	70 x 45 x 6.7 mm
Weight	36.1 g
Cell Type/Packaging	Pouch
Capacity	2.3 Ah
Voltage Range	2.7 - 4.2 V
Nominal Voltage	3.65 V
Nominal Sp. Energy at C/20	236 Wh/kg
Nominal Sp. Energy at 1 C	196 Wh/kg, (83%)
Cycle Life	>1000 cycles (est.)
Operating Temperature	-40 to 60 °C
Max Continuous Discharge	2 C
Max Pulsed Discharge (30 sec)	10 C
Max Charging Current	C/2
Safety Risk	Low (SAE J2464 ≤ 4)

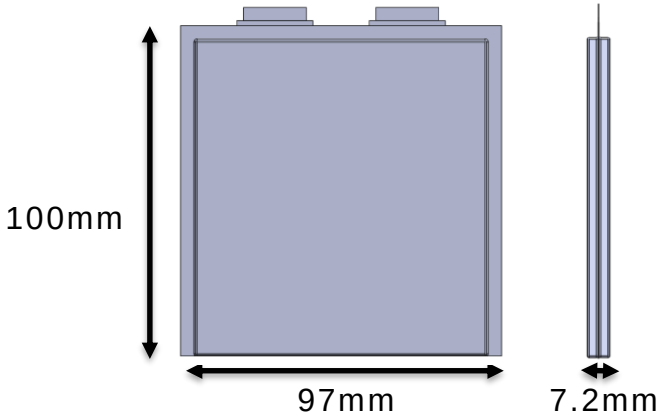






Future Cell (Estimated Specs.)

Specifications	
Size	100 x 97 x 7.2 mm
Weight	155.5 g
Cell Type/Packaging	Pouch
Capacity	10.6 Ah
Voltage Range	2.7-4.2 V
Nominal Voltage	3.65 V
Nominal Sp. Energy at C/20	251 Wh/kg
Nominal Sp. Energy at 1 C	210 Wh/kg, (83%)
Cycle Life	>1000 cycles
Operating Temperature	-40 to 60 °C
Max Continuous Discharge	2 C
Max Pulsed Discharge (30 sec)	10 C
Max Charging Current	C/2
Safety Risk	Low (SAE J2464 ≤ 4)



Presentation Outline

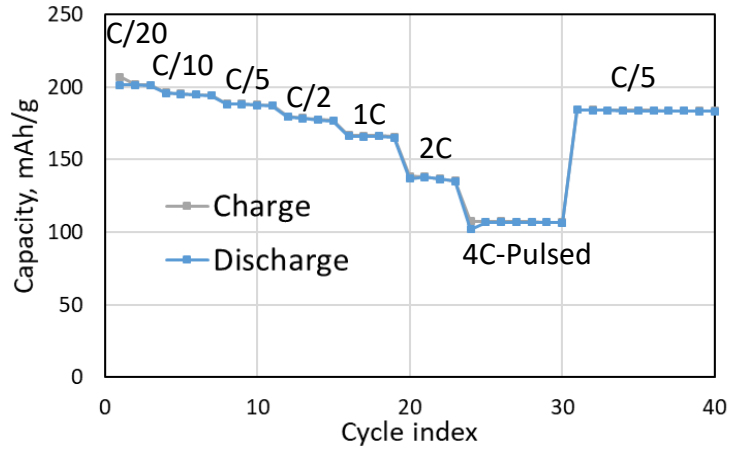
Company Overview

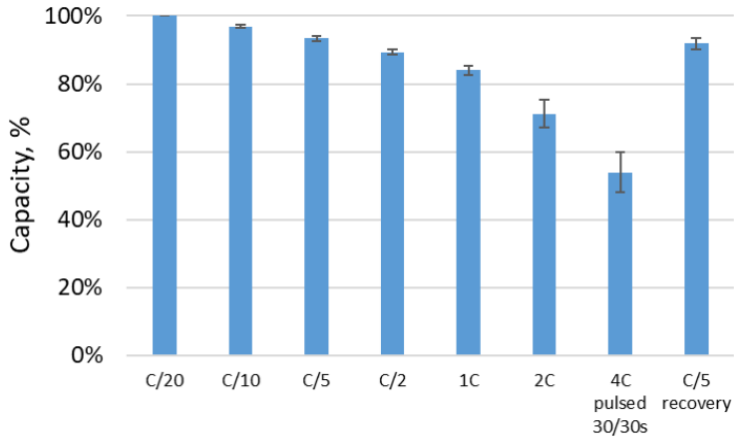
Cell Design

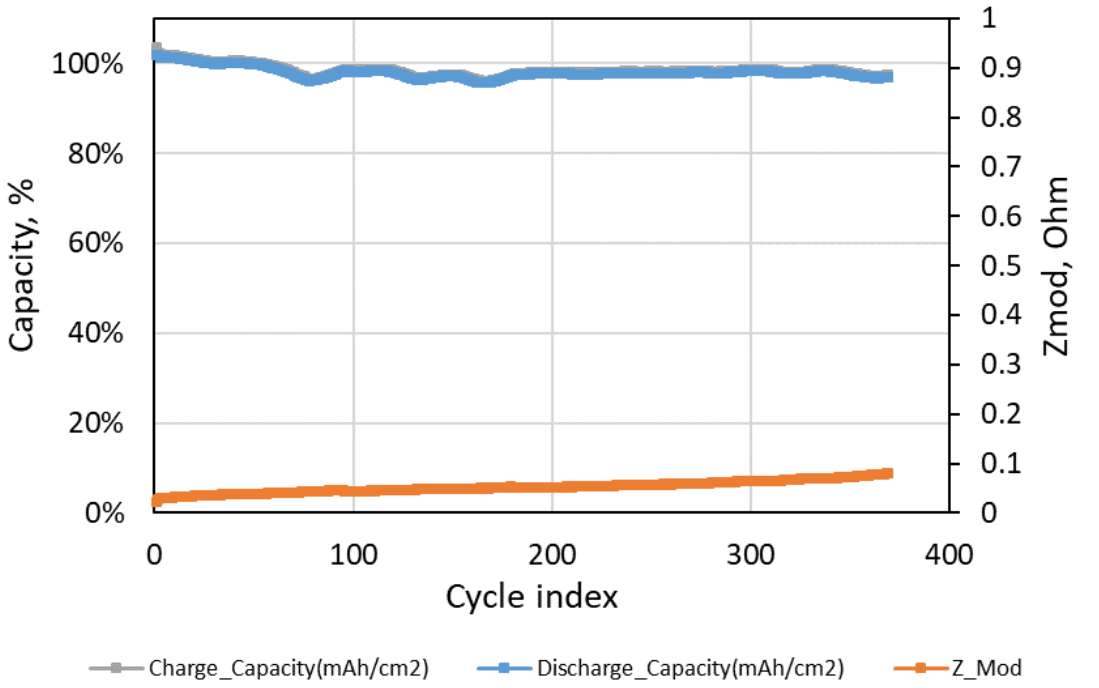
Cell Performance

Applications

Rate and Cycle Life Performance



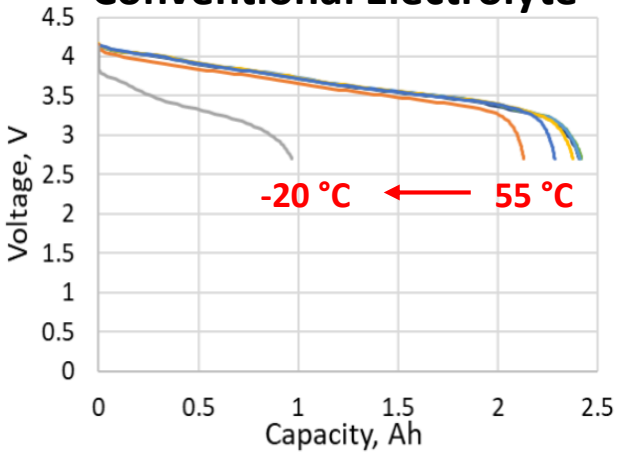




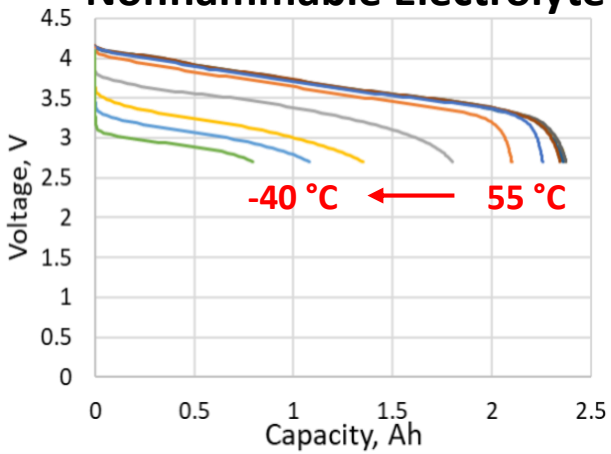
High energy cells have moderate rate and excellent cycle life

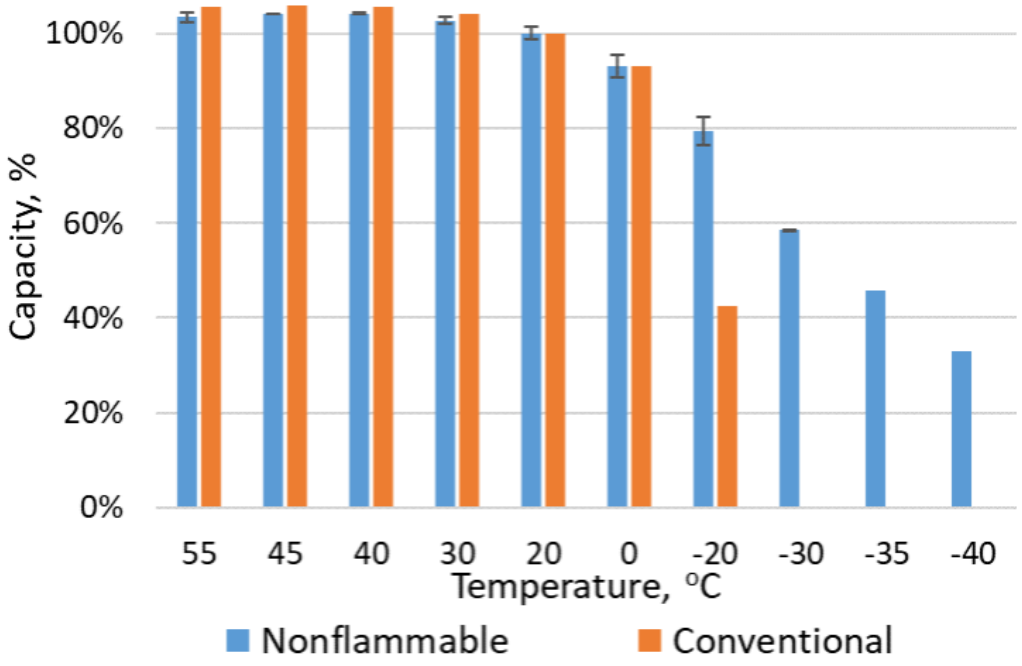
Low Temperature Performance

Conventional Electrolyte



Nonflammable Electrolyte

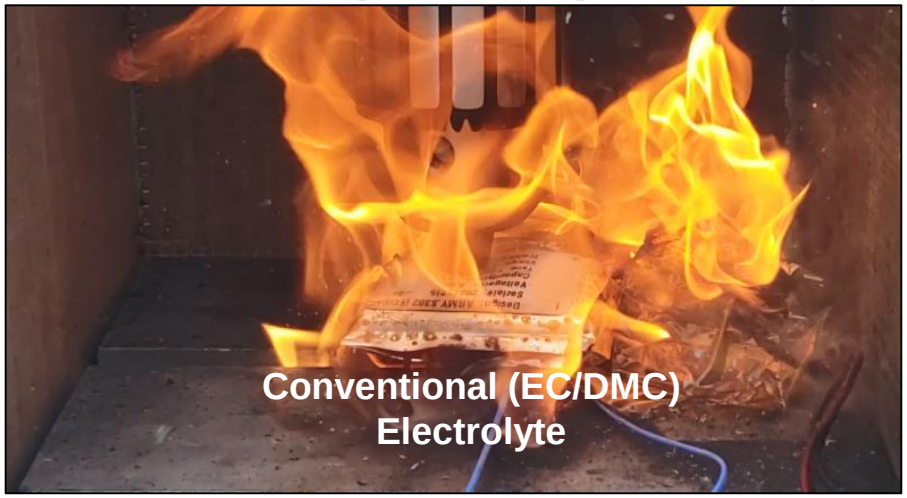


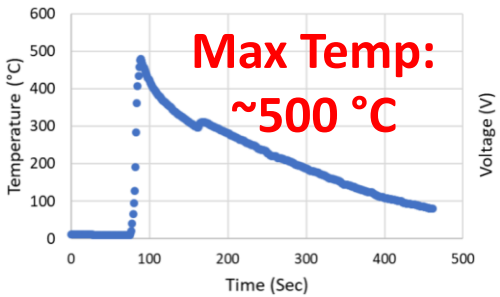


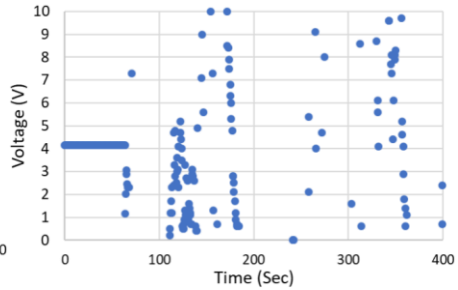
Nonflammable cells demonstrate excellent temperature stability, even at extremely low temperatures

Nail Penetration

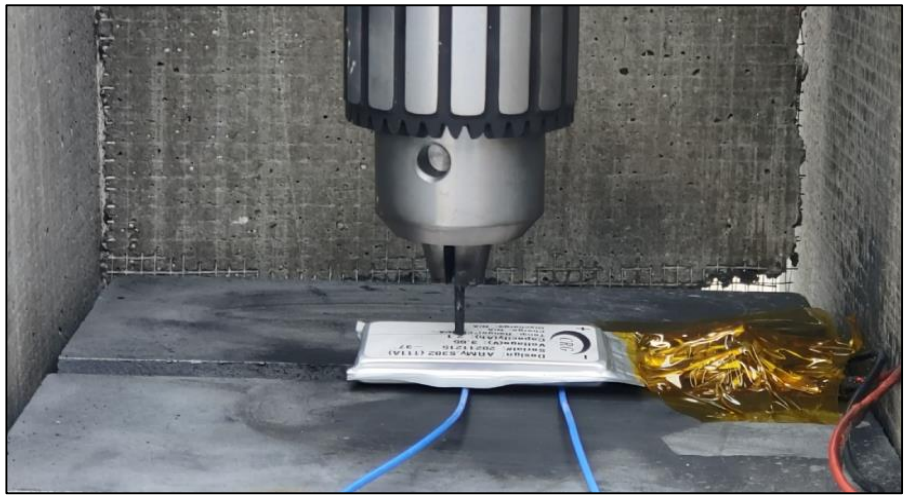
Conventional (EC/DMC) Electrolyte

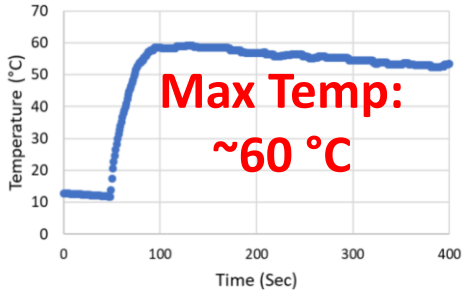


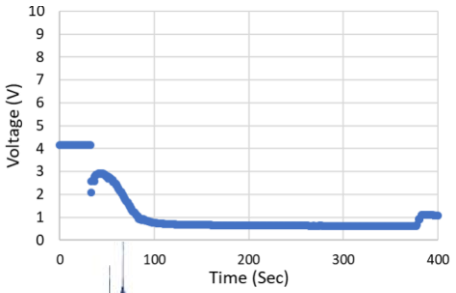




CRG Nonflammable Electrolyte



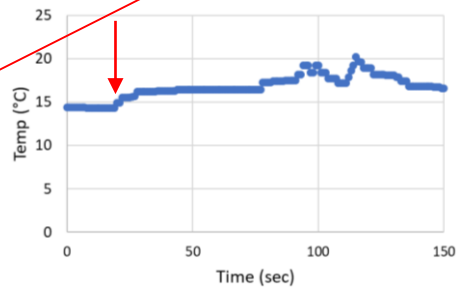




External Short

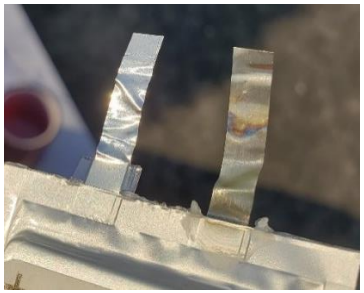
Hard-Short (<100 mΩ)

- Nickle tab melted almost instantaneously (< 1 sec)
  - Acted similar to a fuse
- Limited to no rise in temperature
- HSA ≤ 2 (damage, no hazard)

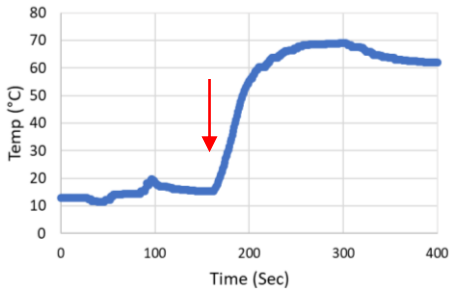


Soft-Short (~1 Ω)

- Estimated at ~30 Amps
- Nickle tab gets red hot, but does not melt
- Cell temperature increases to ~70 °C, well within safe range
- HSA = 0 (no effect or function)

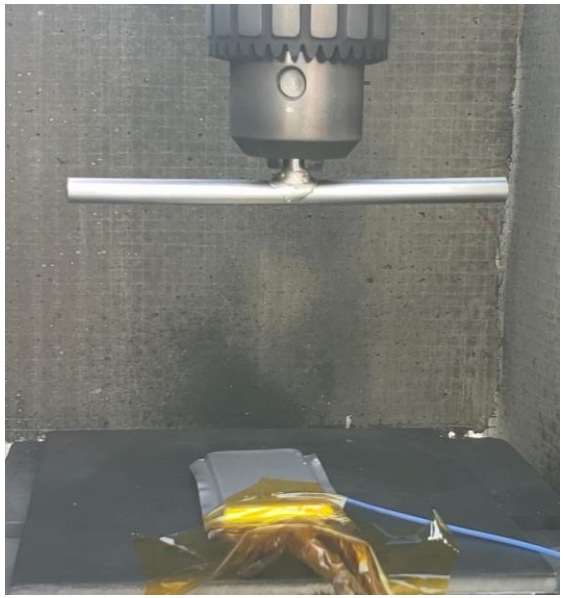


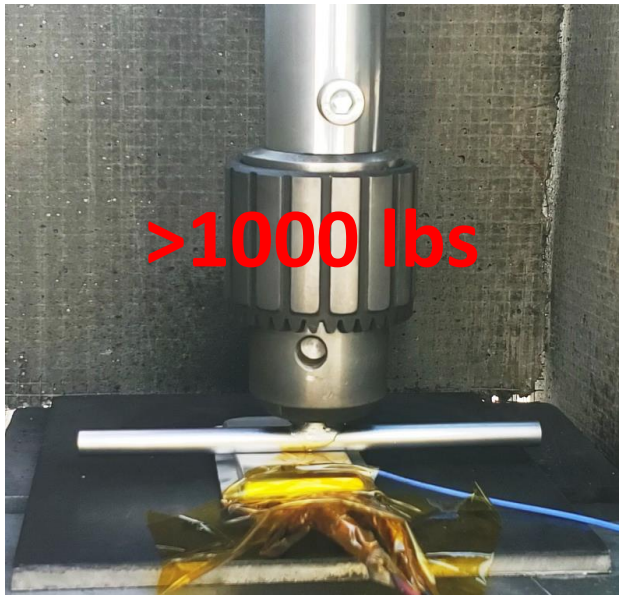
Estimated at ~30 Amps

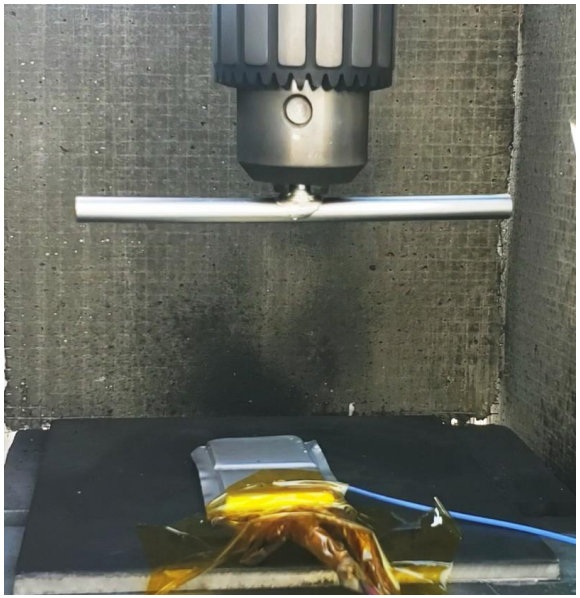


The nonflammable cell remained safe throughout external short abuse testing

Crush Test







- Max pressure ~1100 lbs
- 3/8” diameter rod
- No internal short (voltage steady)
- No temperature rise

Cells showed ~10% deformation from crush but it had no effect on cell performance

Ballistic Penetration

Rifle round (7.62 mm)

Conventional Electrolyte

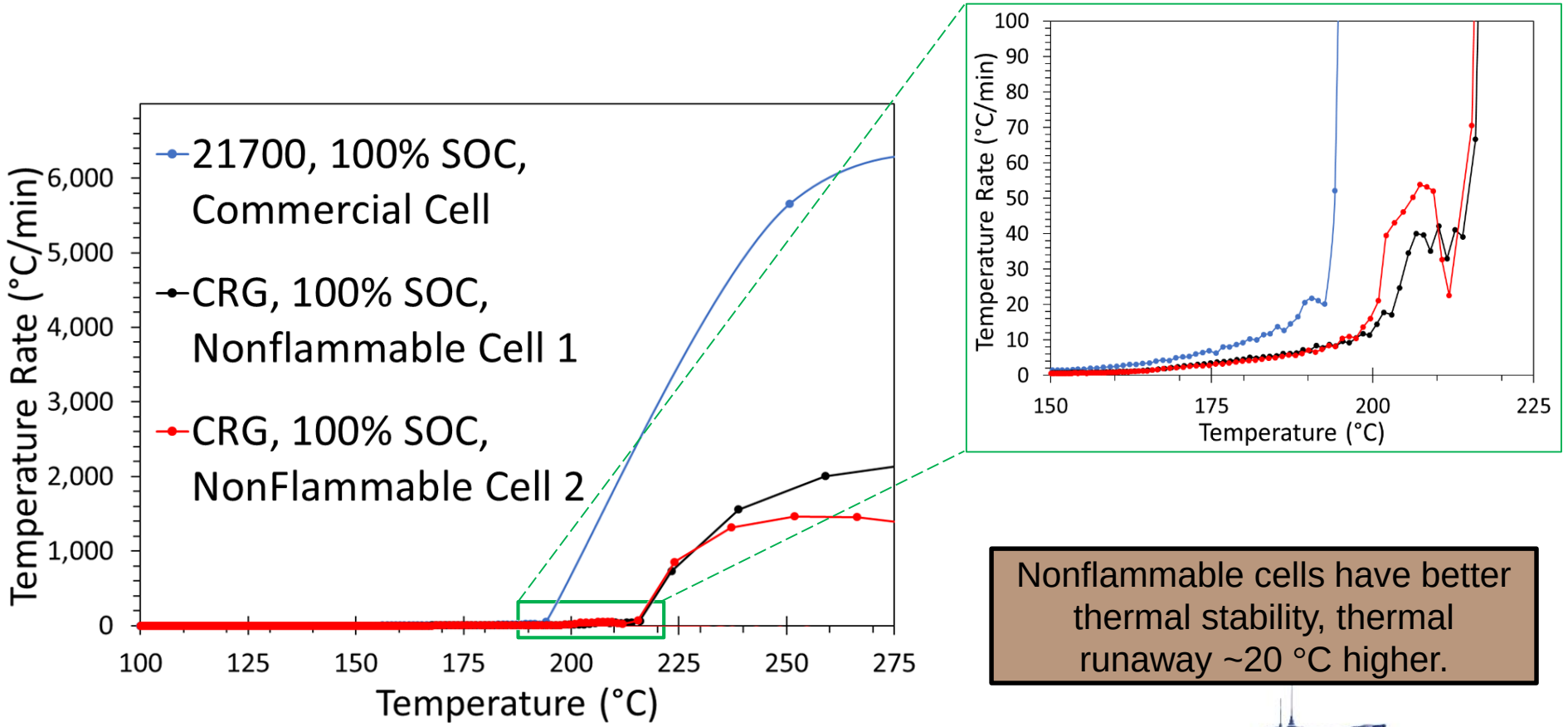
Nonflammable Electrolyte

Incendiary Tipped Round (7.62 mm)

Nonflammable Electrolyte

Nonflammable cells demonstrate no smoke/flames during ballistic penetration, even with incendiary rounds

Arc Testing (Thermal Runaway)



Nonflammable cells have better thermal stability, thermal runaway ~20 °C higher.

Presentation Outline

Company Overview

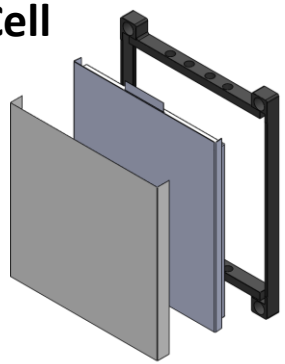
Cell Design

Cell Performance

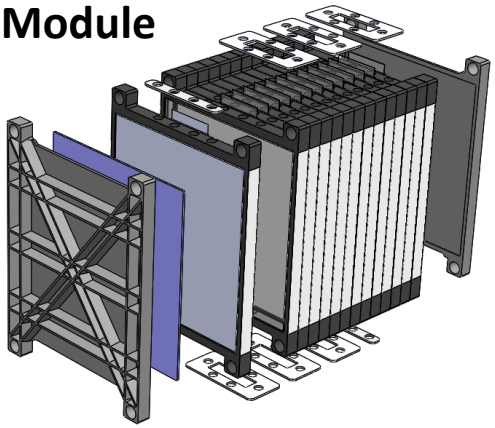
Applications

Vehicle Battery (6T)

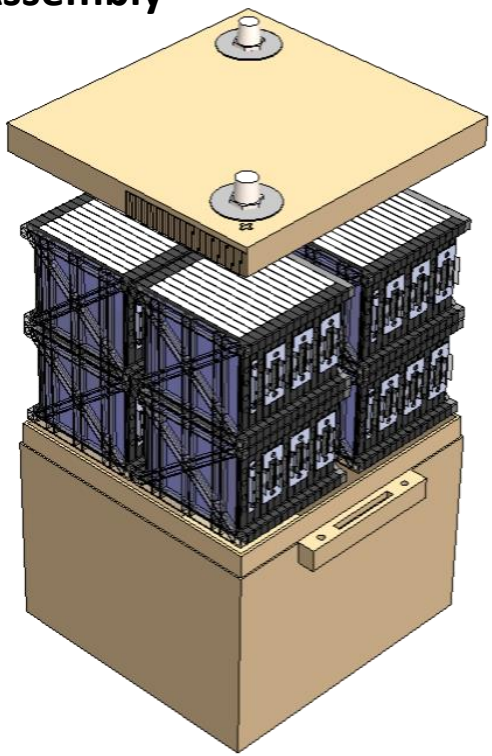
Pouch Cell



Module



Battery Assembly



6T Pack Level		
Config	7x16	(S x P)
Total Cells	112	Cells
Voltage	25.9	V
Total Cell Fill	58.0%	%
Mass	25	kg
Capacity	169	Ah
Specific Energy	175.6	Wh/kg

Defense Application

- Hybrid/electric ground vehicle
  - Fault tolerant high energy batteries
  - 6T or custom format packs
- Ballistic Conformal Battery
  - 150 Wh w/armor protection
  - Ballistic survivable power source
- Unmanned Air Systems
- Man portable radio/comms battery
- Maritime propulsion

Questions?

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